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(54) Measurement of carbon in ash

(57) In a method of measuring the number of carbon particles in ash produced by boilers (10) used in the generation of electricity, a sample of ash is formed into a monoparticulate layer or a cake having a flat surface and an image of the layer or surface is formed by a CCD camera/microscope unit at a monitor station (12). The image is digitised and by comparison with appropriate reference levels at central processor means (14) the particles are categorised by both colour and shape. The numbers of particles in each category can then be displayed at a suitable display (16) to provide operating personnel with an indication of the proportion of carbon particles in the ash. Particles are identified as carbon particles when they are non-spherical and black.

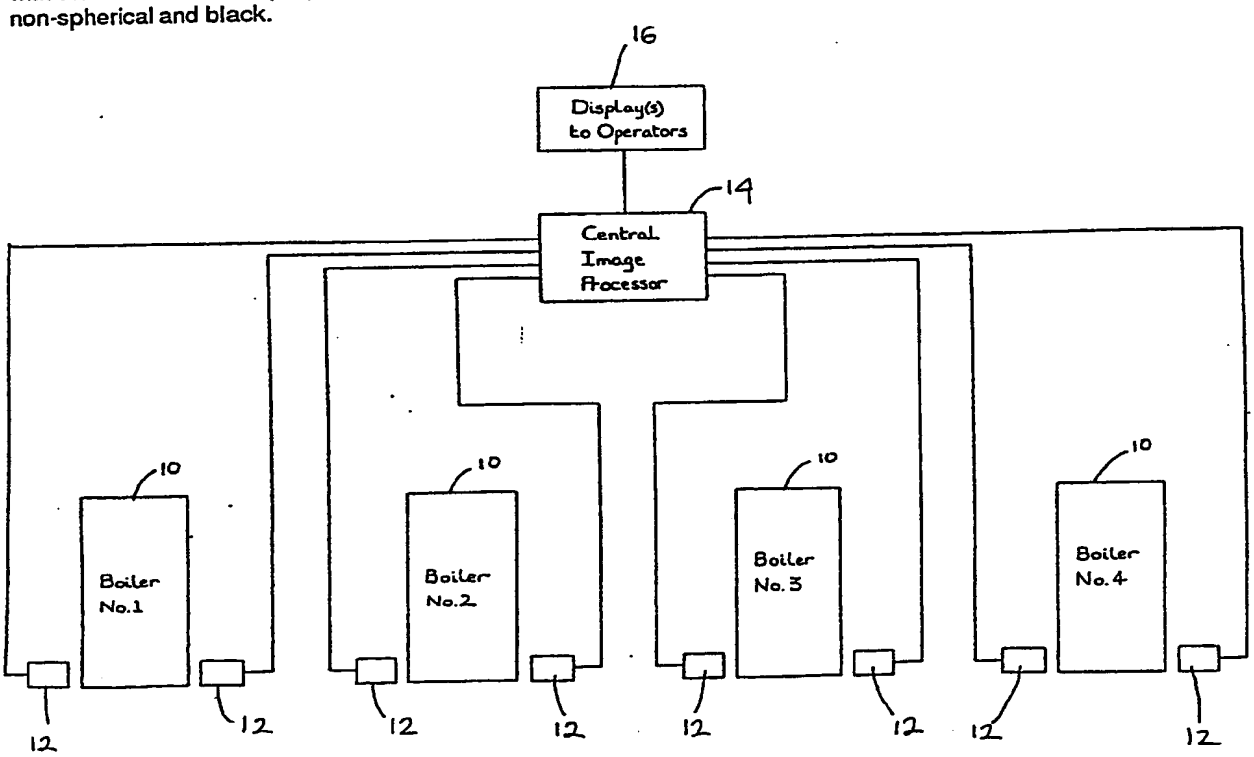

Fig. 1.

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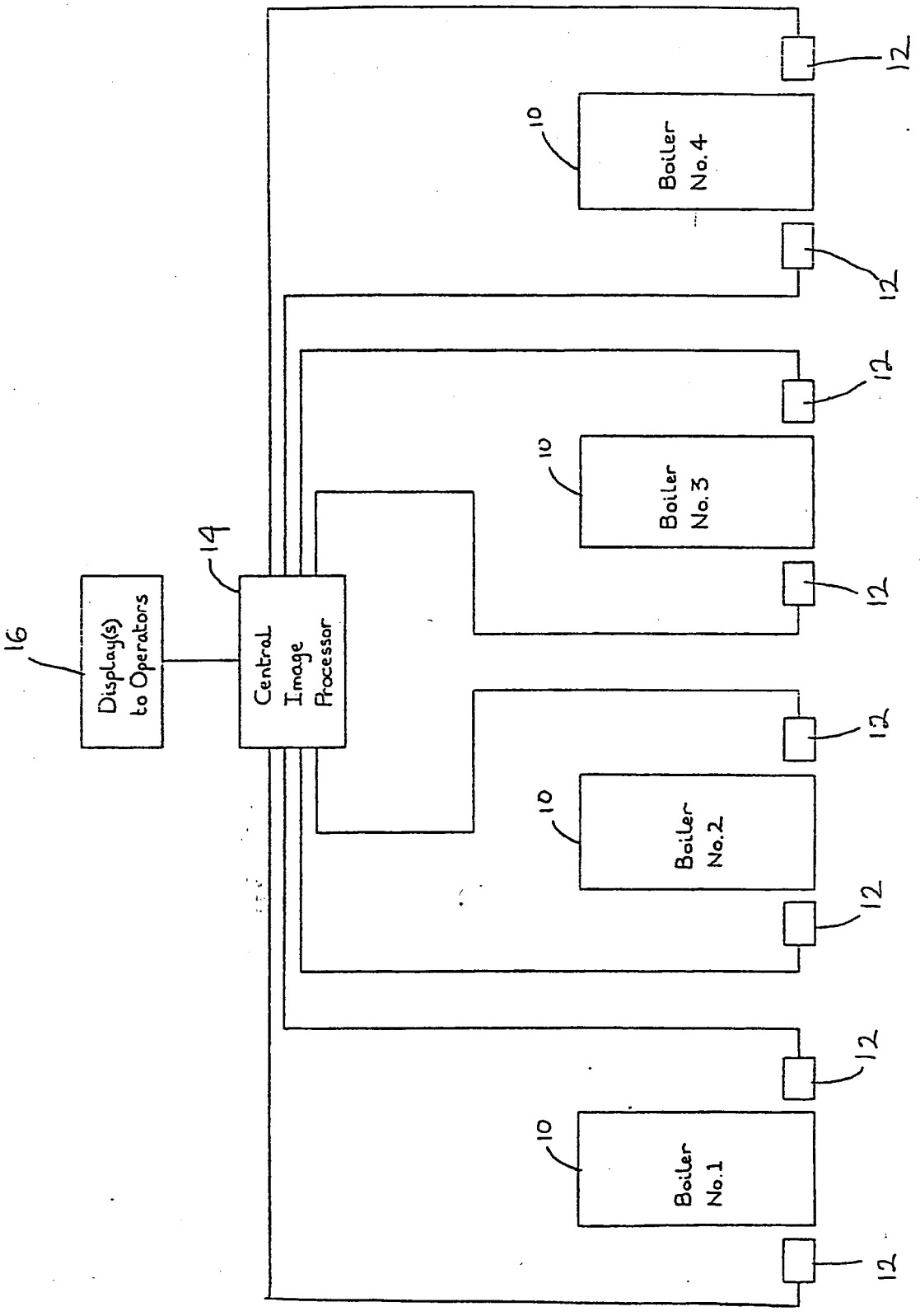
Boiler No.4
Boiler No.3
Boiler No.2
Boiler No.1
10
12
14
16
Central Image Processor
Display(s) to Operators

FIG. 1.

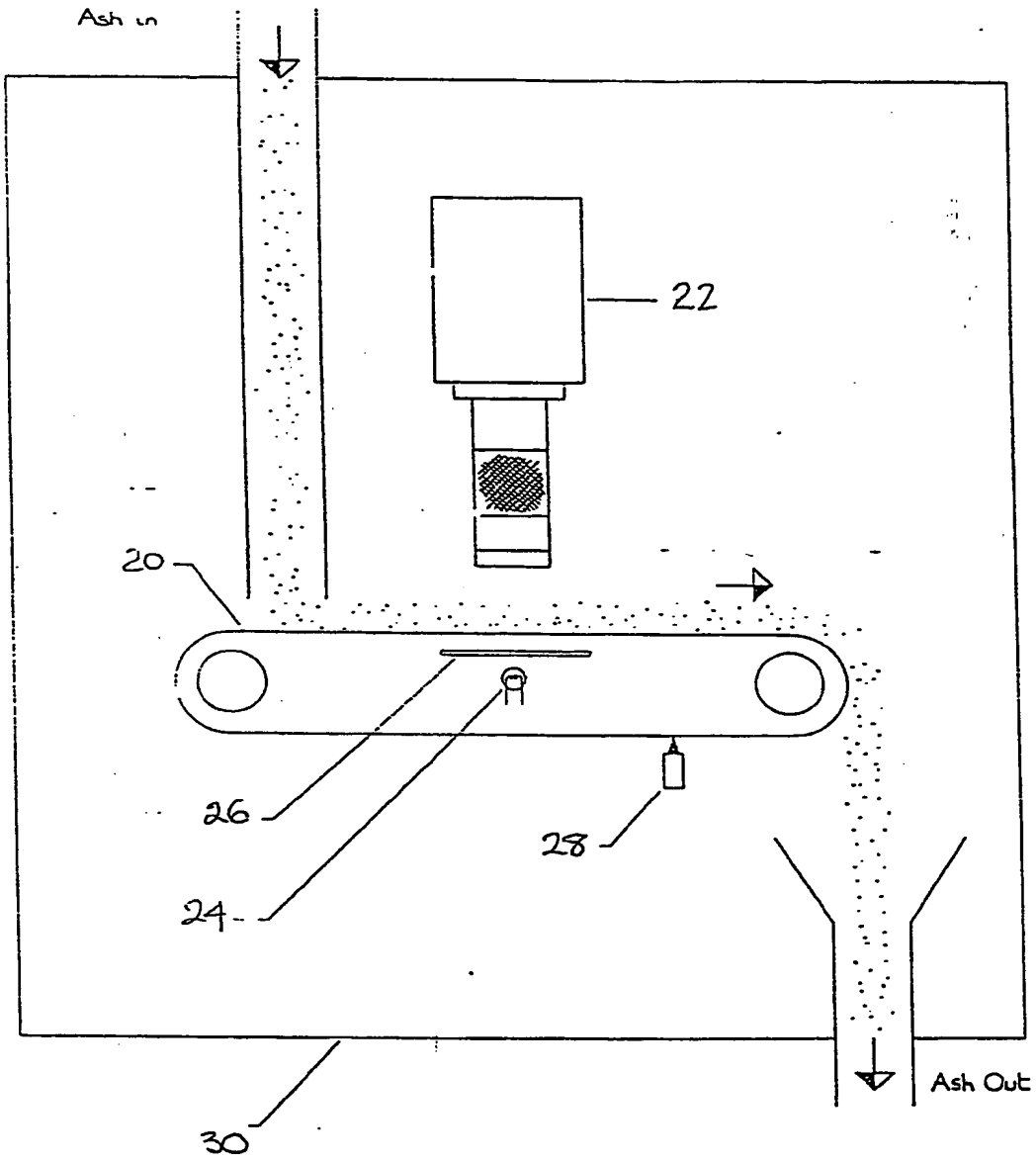

FIG. 2.

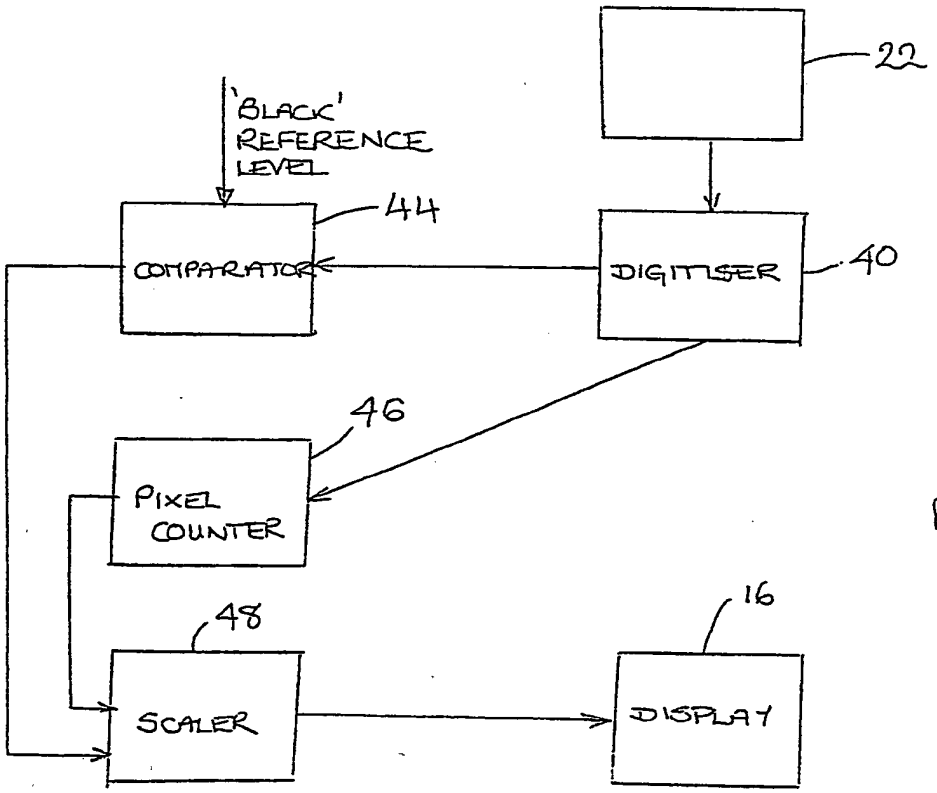
22
'BLACK' REFERENCE LEVEL
44
COMPARATOR
DIGITISER
40
46
PIXEL COUNTER
48
SCALER
16
DISPLAY

FIG.3.

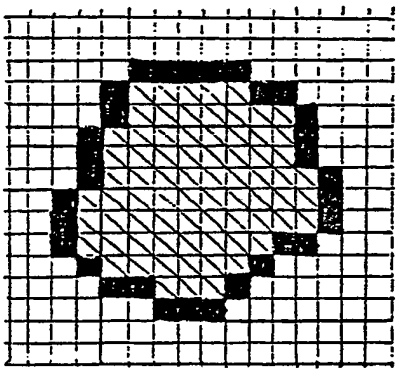

FIG.4.

MEASUREMENT OF CARBON IN ASH

The present invention relates to a method and apparatus for detecting and monitoring the presence of carbon particles in ash produced by boilers used for industrial purposes, in particular, in generating electricity. It is, of course, desirable that the proportion of carbon particles in ash be readily detectable so that it can be ensured that the boiler is burning fuel efficiently and that regulations intended to reduce atmospheric pollution are complied with.

There are currently a number of devices on the market for making such measurements but these are expensive, costing over £30,000 each, and require a substantial amount of maintenance.

In the monograph "The Identification of Atmospheric Dust by Use of the Microscope" by E.M. Hamilton and W.D. Jarvis (Central Electricity Generating Board Research Department) it is noted that coal (carbon) particles are the only particles present in the ash (dust) that are non-spherical and black. This is supported by the illustrations accompanying the monograph which show all the significant types of particles occurring in the ash output from a pulverised fuel power station. These fall, in general, into three categories as follows:-

(i) Spheres (ash): coal impurities melt to form molten drops that solidify as spheres of various colours;

(ii) Shale particles (ash): these are white, irregularly shaped particles consisting of impurities from the coal that did not melt; and

(iii) Unburnt fuel (carbon): these are black, irregularly shaped particles of pulverised fuel.

We have concluded from this that it would be possible to determine the proportion of carbon in ash by visual inspection.

In accordance with the invention, there is provided a method for analysing particulate material in which particles in a sample of the said material are formed into a method for analysing particulate material in which particles in a sample of the said material are formed into a substantially monoparticulate

layer or cake having a flat surface, the said particles are categorised according to their appearance and the numbers of particles in each said category is calculated so as to provide an indication of the proportions of particles of different categories in the sample. The said particles are categorised according to their appearance. The area and the number of particles in each said category are calculated so as to provide an indication of the proportions of particles of different categories in the sample.

Preferably, the particles are categorised by both colour and shape.

The invention further provides apparatus for analysing particulate material, the apparatus comprising means for forming particles in a sample of the said material into a substantially monoparticulate layer or a cake having a flat surface; means for providing an electrical signal representative of an image the particles in the said layer or surface; and processor means for categorising the particles shown in the said image according to their appearance and for calculating the number of particles in each category so as to provide an indication of the proportions of particles of different categories in the sample; means for providing an electrical signal representative of an image of the particles in the said layer or surface; and processor means for categorising the particles shown in the said image according to their appearance and for calculating the number of particles in each category so as to provide an indication of the proportions of particles of different categories in the sample.

A preferred method and apparatus in accordance with the invention will now be described in detail, by way of example, with reference to the drawings, in which:

Figure 1 shows schematically the arrangement of monitors for use in the method of the invention;

Figure 2 shows an arrangement for viewing ash particles in the method of the invention;

Figure 3 shows in greater detail the processor of Figure

2; and

Figure 4 shows a digital image of a single particle.

In order to measure the proportion of carbon particles in ash, a small but representative sample of boiler ash is collected from the output flues of power station boilers 10 and monitored by means of electro-optical monitors 12 at the ash collection points, as shown in Figure 1. The output signals from the monitors 12 are processed centrally at an image processor 14, the output signal from which is displayed in suitable form at display 16 for personnel operating the boilers.

The ash is collected from the boiler flues in a conventional manner and is transported to the monitoring stations 12 shown in detail in Figure 2. The ash falls onto a continuous conveyor belt 20 and is formed into either a discrete monoparticulate layer, assisted if necessary by vibration, or a cake, dressed by rolling or a similar process. The ash sample is illuminated by a suitably positioned light source. Where the ash is formed into a monoparticular layer, the conveyor belt 20 may be translucent and back-lighting of the particles provided by means of a light source 24 and associated diffuser 26 mounted beneath the conveyor belt 20 as shown in figure 2. The ash sample on the conveyor belt 20 passes beneath a camera/microscope unit 22 consisting of a CCD or other array scanned camera fitted to a microscope. The camera/microscope unit 22 provides magnification of the order of, say, 50-150x. Once the ash on the conveyor belt has passed beneath the camera/microscope unit 22 it falls, at the end of the conveyor 20, into an ash outlet. A brush 28 is provided at the return side of the conveyor 20 to ensure that ash, once it has passed in front of the camera/microscope unit, is not recirculated but is removed from the monitoring station 12. The conveyor 20, its light source 24 and the camera/microscope unit 22 are housed within a light-proof box 30 so as to provide the best possible image at the camera/microscope unit 22 for processing to identify carbon particles.

An alternative to the conveyor arrangement described would be to drive the ash through a suitably illuminated glass tube using compressed air.

The output signal from each CCD camera/microscope unit 22 is passed to a digitiser 40 which provides a digital representation of the image "seen" by the camera/microscope unit 22. Suitable space and grey level resolution for the purposes to be described below have been found to be 512x512 pixels and either 128 or 256 grey levels.

The digital image provided by the digitiser 40 is then analysed to identify individual particles and distinguish them from their background. In practice, the various steps carried out by the central processor 14 can be implemented by the use of suitable software installed on a personal computer. Figure 3, however, illustrates how the digital image is analysed.

Once the particles appearing in the image have been identified, they must be classified as black or non-black and as spherical or non-spherical. As mentioned above, the only particles found in ash which are black and non-spherical are carbon particles, that is, particles of unburnt fuel.

The distinguishing of black from non-black particles is a simple thresholding operation. The average grey level of the pixels forming the image of a given particle is compared with a "black" reference level at comparator 44. The output of the comparator 44 provides a straightforward indication as to whether the particle is black or non-black.

Spherical particles can be distinguished from non-spherical particles by counting the number of pixels inside the boundary of the digitised image of the particle, the particle area, and comparing it at pixel counter 46 with the number of pixels around the edge of the particle image, the particle periphery. Thus, for the example shown in Figure 4, the number of pixels around the particle periphery (shaded in black) is thirty-one and the number of pixels within the particle area (shaded in black and cross-hatched) is one hundred and five. By comparing the ratio of the square of the number of pixels in the periphery with the number in the particle area, it is possible to determine how close to spherical a given particle is. Again by comparison with a suitably chosen threshold, particles can be categorised as spherical or non-spherical.

From this categorisation of particles, it is possible to

derive a figure giving the ratio of carbon to ash by visible surface area. This figure can in turn be converted by use of a suitable scaler 48 to provide a ratio by volume or by weight. Preferably, the final figure representing the ratio of carbon to ash particles is produced from the moving average of a number of readings so that it is less subject to noise than analysis based on only a single frame. It is expected that each image from the CCD camera/microscope unit 22 will be processed in under three seconds. Thus, for a four boiler unit, the carbon-in-ash figure will be updated every twenty-four seconds or so.

The system described above has a number of advantages over existing systems. It can be built relatively cheaply because a single processor can handle the output from several microscopes. Furthermore, because it uses a non-contact method it should be relatively robust in comparison to other systems which involve heating and chemical analysis of ash samples.

CLAIMS

1. A method for analysing particulate material in which particles in a sample of the said material are formed into a substantially monoparticulate layer or cake having a flat surface, the said particles are categorised according to their appearance and the numbers of particles in each said category is calculated so as to provide an indication of the proportions of particles of different categories in the sample.

2. A method according to claim 1 in which the layer of particles is passed before a camera which provides an electronic output signal representative of an image of the particle layer or surface, the said electronic output signal being digitised and the resulting digital signal being used in the categorising of the particles.

3. A method according to claim 2 in which the particles are categorised by colour.

4. A method according to claim 3 in which the grey level of pixels of the digital signal representing each particle is compared with at least one reference level to provide an indication of particle colour.

5. A method according to any preceding claim in which the particles are categorised by shape.

6. A method according to claim 5 in which the shape of each particle is characterised by determining the ratio of the number of pixels along the periphery of the digital image of the particle to the number of pixels within the area of the particle in the digital image.

7. A method according to claim 6 in which the said ratio is compared with at least one reference level to provide an indication of particle shape.

8. A method according to any preceding claim in which the categorisation is repeated using a plurality of different samples and the results averaged to provide an indication of the proportions of particles of different categories.

9. A method for analysing particulate material, the method being substantially as hereinbefore described with reference to the drawings.

10. A method according to any preceding claim for determining the proportion of carbon particles in ash.

11. Apparatus for analysing particulate material, the apparatus comprising means for forming particles in a sample of the said material into a substantially monoparticulate layer or a cake having a flat surface; means for providing an electrical signal representative of an image the particles in the said layer or surface; and processor means for categorising the particles shown in the said image according to their appearance and for calculating the number of particles in each category so as to provide an indication of the proportions of particles of different categories in the sample.

12. Apparatus according to claim 11 in which a digitiser acts on the electrical signal representing the image of the particles and the processor means acts on the resulting digital signal.

13. Apparatus according to claim 12 in which the processor means acts to categorise the particles by colour.

14. Apparatus according to claim 13 in which the processor means includes means for comparing the grey level of pixels of the digital signal representing each particle with at least one reference level to provide an indication of particle colour.

15. Apparatus according to any of claims 11 to 14 in which the processor means acts to categorise the particles by shape.

16. Apparatus according to claim 15 in which the processor means includes means for counting the number of pixels along the periphery of the digital image of each particle and the number of pixels within the area of the particle in the digital image, and for determining the ratio of these numbers.

17. Apparatus according to claim 16 in which the processor means includes means for comparing the said ratio with at least one reference level to provide an indication of particle shape.

18. Apparatus for analysing particulate material, the apparatus being substantially as hereinbefore described with reference to the drawings.

19. Apparatus according to any of claims 11 to 18 for determing the proportion of carbon particles in ash.

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Patents Act 1977
Examiner's report to the Comptroller under Section 17 (The Search Report)

Application number 9024645.5

Relevant Technical fields

(i) UK Cl (Edition K) G1A AAJ

(ii) Int Cl (Edition 5) G01N; G06F

Search Examiner

M J JONES

Databases (see over)

(i) UK Patent Office

(ii)

Date of Search

4 February 1991

Documents considered relevant following a search in respect of claims 1-19

Category (see over)	Identity of document and relevant passages	Relevant to claim(s)
X	GB A 2,042,717 (LOCKWOOD)	1,2,11, 12
X	GB 1,490,070 (METALS)	1,2,3, 11,12,13
X	EP A2 0,147,802 (TOBACCO)	1,2,11, 12
X	WO A1 87/07024 (HUGHES)	1,11
X	WO A1 83/00556 (MITSUBISHI)	1,11
X	US 4,497,576 (FRANCAIS) See Column 3 Line 51	1,2,11 12

SF2(p)

Category	Identity of document and relevant passages	Relevant to claim(s)

Categories of documents

X: Document indicating lack of novelty or of inventive step.

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P: Document published on or after the declared priority date but before the filing date of the present application.

E: Patent document published on or after, but with priority date earlier than, the filing date of the present application.

&: Member of the same patent family, corresponding document.

Databases: The UK Patent Office database comprises classified collections of GB, EP, WO and US patent specifications as outlined periodically in the Official Journal (Patents). The on-line databases considered for search are also listed periodically in the Official Journal (Patents).

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